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Protection Range Estimation for Light Armour Configurations

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Abstract

A method is presented which allows the protection characteristics of light armour to be rapidly calculated and displayed as a function of range and azimuth. The use of detailed empirical data on projectile performance against the armour as a function of range and obliquity allows an accurate description of the protection characteristics. However, the method is also shown to be useful with as little data as the velocity/range data for the projectile and the thickness of armour defeated at normal impact, at the projectile muzzle velocity.

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Contents

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1. Introduction

A complete description of the vulnerability of an armoured vehicle to anti-armour munitions is a combination of the probability of hit as a function of range, the probability of perforation for the impact position, angle and velocity, and the probability of some kill of a critical component in terms of its presented area, "hardness" and the residual projectile mass and velocity. Unfortunately all elements of this data set are not always available, and component vulnerability data, in particular, is often at best only broadly indicative of expected behaviour. A simpler approach to assessing the survivability of an armoured vehicle when attacked by kinetic energy munitions is estimation of the protection range — the range at which the vehicle armour cannot be perforated. This note demonstrates how protection range can be estimated from a very limited data set. The method maximizes the utilization of limited data and provides a quick assessment procedure for vehicle capability. The method is first illustrated by presenting a sample problem using a fictitious vehicle and armour piercing rounds. The technique is then justified, and that discussion indicates how accuracy is enhanced with greater use of empirical data.

2. Example Problem

Figure 1 shows a model light armoured vehicle constructed of hard steel armour. The protection provided by this armour against an 11 mm armour piercing projectile is to be assessed. For the projectile we have data on velocity as a function of range, Figure 2(a). This is easily calculated if the muzzle velocity, mass and form of the projectile is known [1]. Also available is the thickness of armour the projectile will defeat at the muzzle velocity as a function of angle of obliquity, Figure 2(b). If the latter relation is not known, rather just the thickness penetrated

at zero obliquity, h_o, then the curve can be estimated conservatively, but to reasonable accuracy, using the equation

$$h_\theta = h_o \cos \theta \qquad (1)$$

where θ is the impact obliquity, the angle between the projectile line of flight and the normal to the armour plate

and h_θ is the thickness of armour defeated at angle θ.

Equation (1) assumes that the only effect of obliquity is to increase armour thickness along the line of flight and is represented by a dashed line in Figure 2(b). Also shown on this figure are the thickness of vehicle armour and its obliquity as in Figure 1.
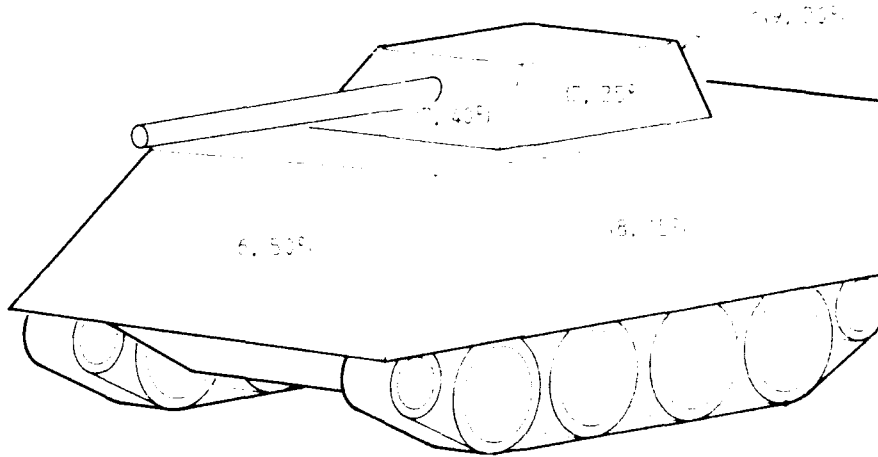

Figure 1: Simplified armoured fighting vehicle using a range of armour thicknesses and obliquities on the front, sides and back of the hull and turret.

If it is assumed that the thickness of armour, h, penetrated by an armour piercing projectile is proportional to its kinetic energy then we have a relation of the form

$$h = kv^2 \qquad (2)$$

connecting thickness to the projectile impact velocity v, where k is a constant. Thus using the curve of Figure 2(b) the thickness penetrated at the muzzle velocity is used

to determine k for a particular impact obliquity. For that impact obliquity several thicknesses are then calculated for reduced velocities using equation (2) (and corresponding increased ranges read from Figure 2(a)) to construct a plot of penetration capability as a function of range. This is repeated for several impact obliquities, at each of which a new value of the constant k is determined, so that a graph of the form of Figure 2(c) represents penetration/range characteristics at appropriate impact angles. In some instances empirical data is available for projectile/armour combinations for penetration capability as a function of velocity (and range) at several impact obliquities. Under such circumstances Figure 2(c) may be constructed more accurately as the assumptions inherent in equation (2) are not required.

We consider a projectile fired towards the armour at an angle ϕ to the plate normal in the horizontal plane. When this angle is combined with the angle at which the armour is tilted in the vertical plane, χ, we obtain the total or compound obliquity, θ. From Figure 2(c) the range at which the vehicle can be defeated at any azimuth is easily read. The horizontal line in Figure 2(c) shows that 7 mm armour will provide protection beyond 440 m range at 25° obliquity (the turret side angle). This armour thickness will also protect beyond 280 m at 40° compound obliquity, and at zero metres at 54° compound obliquity. The latter can be read directly from Figure 2(b) by moving horizontally to see at what angle the 7 mm armour is just defeated by the projectile. The compound angles, θ, are then readily converted into the angle ϕ normal to the plate, in the horizontal or azimuth plane using the formula

$$\tan \phi = (\tan^2 \theta - \tan^2 \chi)^{0.5} \tag{3}$$

These three data points are plotted in Figure 3 where range is shown radially and is plotted with zero normal to the turret side for the turret side armour . Completing the analysis for front, rear and side of both hull and turret gives a complete description of the vehicle protection as shown in Figure 3.

3. Discussion

The present method has several advantages. It gives a simple and rapid hand calculation approach to estimating protection ranges, and is amenable to formulation into an algorithm for computation. It minimizes the requirement for input data; at minimum the muzzle velocity, calculated velocity/range data and depth of penetration into the armour at the muzzle velocity are sufficient data. Accuracy is increased as the set of empirical performance data becomes more complete. If the vehicle is made of different armour types, then Figure 2(c) needs to be constructed for each type. In the present instance homogeneous hard steel armour is used, but the behaviour of more complex armours may not be approximated as well by equations (1) and (2) so the more experimental data which is available the better the confidence in the results.

The justification of the method is that if Figure 2(c) is constructed from a full empirical set of penetration, range, impact obliquity data, then it is accurate. Relaxations from the use of empirical data to approximate analytical relations do not invalidate the technique, they just reduce the accuracy and confidence.
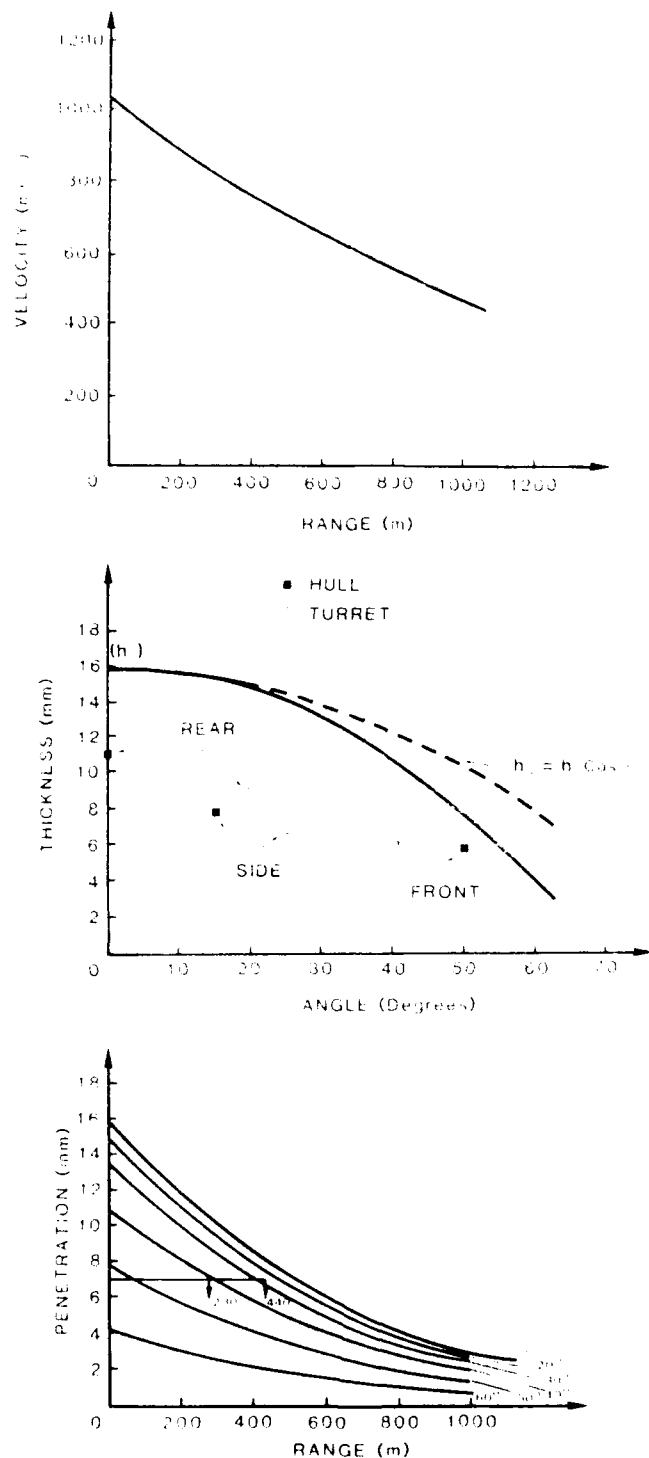
Figure 2: *(a) Projectile velocity as a function of range. (b) Projectile penetration capability at the muzzle velocity as a function of impact obliquity. Also shown dashed is a curve constructed by using equation (1), and armour thicknesses and obliquities for the vehicle of Figure 1 are plotted as points. (c) Projectile penetration capability as a function of range for different impact obliquities. The horizontal line is drawn for the turret side armour.*
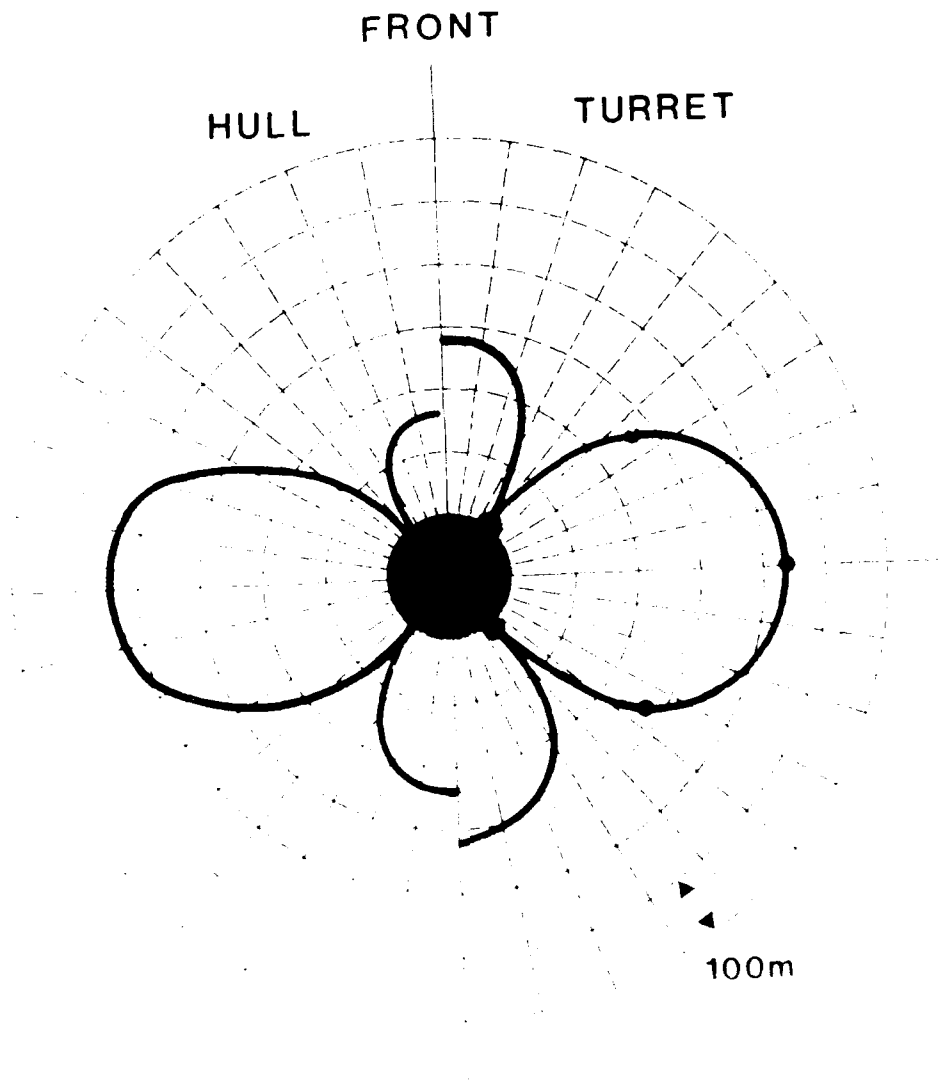
Figure 3: *Vehicle protection range as a function of azimuth for the vehicle characteristics plotted in Figure 2(b). The three plotted points are for the turret side as read from the horizontal line in Figure 2(c).*

4. Conclusion

A method has been presented which allows armour protection characteristics to be represented as a function of range and impact obliquity. The method is very conservative in its data requirements and as such provides a quick assessment procedure.

5. Reference

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      Hatcher's Notebook, The Stackpole Company, Harrisburg, Pennsylvania,
      3rd Ed.

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A method is presented which allows the protection characteristics of light armour to be rapidly calculated and displayed as a function of range and azimuth. The use of detailed empirical data on projectile performance against the armour as a function of range and obliquity allows an accurate description of the protection characteristics. However, the method is also shown to be useful with as little data as the velocity/range data for the projectile and the thickness of armour defeated at normal impact, at the projectile muzzle velocity.